

Renewable Natural Gas Clean-up Challenges and Applications

Renewable Resource Workshop

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Report Documentation Page

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Today's Talk

- >Who is GTI
- >What is Renewable Natural Gas (RNG)
- >Challenges for Renewable Natural Gas
- >How do we clean up RNG?
- >Recommendations and Summary

GTI at a Glance...

- Not-for-profit research, with 65+ year history
- > Facilities
 - 18 acre campus near Chicago
 - 200,000 ft²,
 28 specialized labs
- > \$60 + million in revenue
- > Staff of 250
- > A growing business
- > Commercial partners take our technologies to market





& Labs



Flex-Fuel Test Facility



Energy & Environmental Technology Center



Gas Quality and RNG Clean-up

A Sustainable Gas Network Will Include Renewable Sources

Gas Distributors increasingly asked to accept renewable gas.

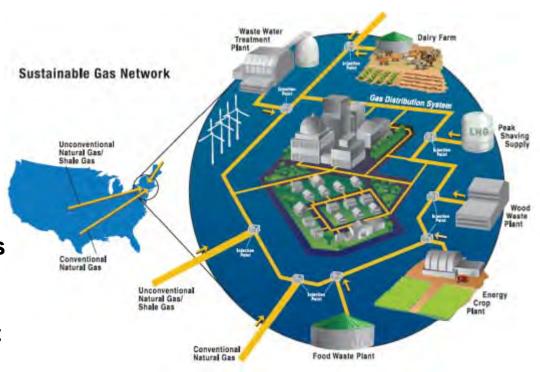
Pipeline tariffs generally don't address "trace" constituents.

Existing clean-up methods are generally intended for on-site use.

Little data on impact of constituents on pipelines or end use equipment

Gas quality research also important for unconventional shale gas supplies.

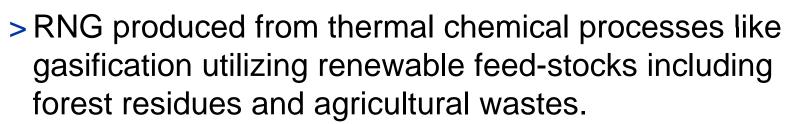
National Grid, Renewable Gas, "Vision for a sustainable gas network", 2010





Renewable Natural Gas is...

- > Methane produced from digesters
 - Animal manure (dairy cows, swine)
 - Waste water treatment facilities
- > Methane from Landfills

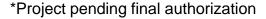


RENEWABLE NATURAL GAS CAN BE CLEANED-UP AND PLACED IN THE NATURAL GAS PIPELINE SYSTEM



GTI RNG Project Examples

- >Example GTI Projects:
 - —Gills Onions
 —Anaerobic digestion of agricultural waste for on-site electricity generation
 - —<u>Altamont Landfill</u>—Landfill gas (LFG) cleanup for production of liquefied natural gas (LNG) for vehicle fuel
 - —Ft. Lewis —Anaerobic digestion of waste water for production of hydrogen as a fuel cell vehicle fuel
 - —SCRA* Landfill gas (LFG) cleanup and on-site reformation to generate hydrogen for MHE in S.C.



Difference between "Conventional Gas and "Renewable Natural Gas"

- >Conventional gas is 95% 98% methane (CH₄)*
 - Constituents are well understood
 - Utilityand Interstate pipeline tariffs account for typical components
 - Methods for treating "raw" gas are proven and in-place
- >RNG is also 95% 98% methane*
 - Constituents are not as well understood
 - Utility and Interstate pipeline tariffs don't typically address all components
 - Methods for treating "raw" biogas can be costly



^{*}Post clean-up. Methane percentage could be lower in some cases

Existing Technologies Can and Do remove trace constituents from RNG

- > CO₂ & O₂ found at % to ppm level concentrations. Tariff limits typical 1-2% (CO₂ & 0.2% O₂
- > Sulfur Compounds (H₂S). Typical tariff is 0.25 grain/100SCF for H₂S and 1 grain/100scf total sulfur
- > Inerts (N₂, He) and H₂
- > Halocarbon compounds
- > Volatile Organics (BTEX, aldehydes, ketones)
- > Ammonia / Amines
- > Siloxanes
- > Mercury and Other Elementals
- > Bacteria and MIC

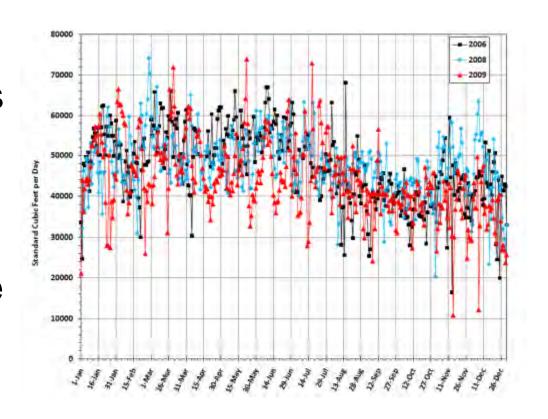


Focus Areas for Improvement Renewable Natural Gas Utilization

- >Supply Stability: Variability in composition & supply
- >Impact on Infrastructure / Pipeline integrity: CO₂, water, H₂ sulfur compounds, NH₃ bacteria, etc.
- >Impact on end use applications:
 - CO2, CO, H2 > flame stability, engine knock,
- >Safety Odorization & leak detection
- >Contaminant Disposal Cleanup media generally not recyclable
- Little Analysis has been performed on biogas for fuel cell applications

Supply Stability

- >Volume variability introduces process configuration challenges
- >Constituents can vary seasonally – or even more frequently
- >Most stable supplies are dairy and swine yards



Daily WWDG Variability on a GTI ongoing project

Why Treat RNG? Impact on Pipeline Infrastructure

>Acid formation from sulfur compounds, carbonic acids, halocarbons or certain bacteria, promoting corrosion



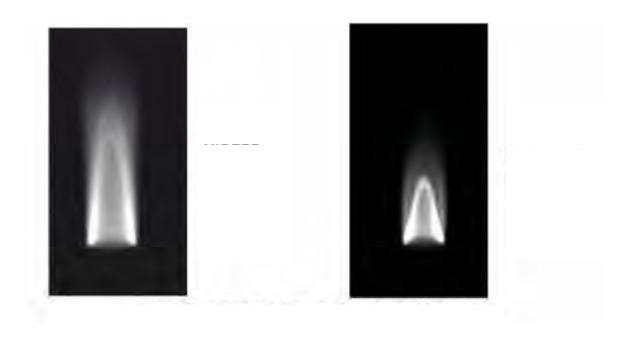
- >Deposits from contaminants
- >Emissions from VOC's introduced into pipeline
- >Water collection



Why Treat RNG? Impact on End Use Applications

- Sas heating value / Wobbe number diminished by inerts in gas stream
- >Deposits from contaminants
- >Emissions from VOC's introduced into pipeline
- >NOx formation from ammonia compounds

High CO2 flame / normal gas flame

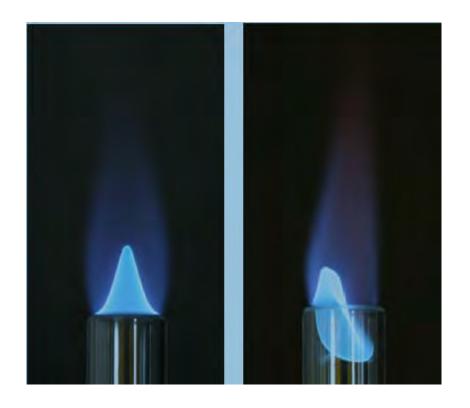


Gas with high CO₂ content

Pipeline quality natural gas

Amell, A. (2007). Influence of altitude on the height of blue cone in a premixed flame. *Applied Thermal Engineering*, 27 (2-3), 408-412.

Normal gas flame / High H2/CO flame



H. Levinsky, KEMA, University of Groningen, The Netherlands



Why Treat RNG? Impact on Fuel Cell Applications

>Impact on Reformer

>Impact on Fuel Cell

- VOC's Coking
- Sulfur compounds catalyst contamination
- Siloxanes silica compounds can coat fuel cell component surfaces
- Halogens (Chlorine, flourine, etc) poison catalyst
- Mercury and other elementals catalyst poison and stack contaminant



Now that we understand the problem, What's the solution?

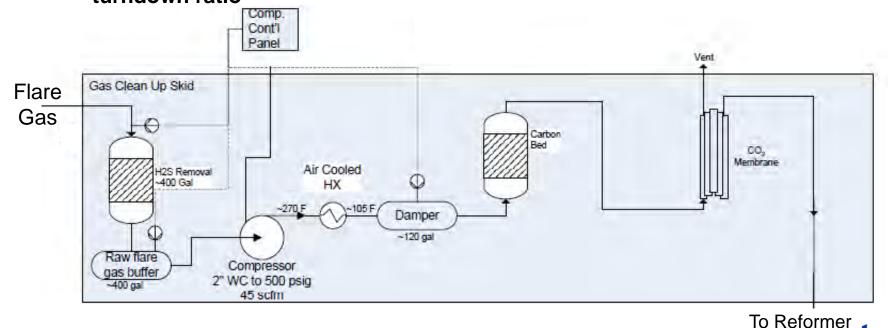
- >Hydrogen generation system from RNG will consist of three key components
 - Renewable natural gas cleanup system (H₂S, CO₂, H₂O removal)
 - Biomethane reformation system (Steam-methane reformation—75-80% efficient)
 - Hydrogen Purification (remaining impurities removed including CO, CO₂,CH₄)

Illustrative Process Flow Diagram for On-site H₂ Supply System

& SOFC Power Generation (Hydrogen Fuel Production at 50kg/day) Tailgas Recovery **Electricity** CH₄: ~13% CO₂ NOx, 12.5 kW Compression CO₂: ~35% products of to move ADG CO: ~1% **Hydrogen Gas** combustion thru clean-up H₂: ~51% (5,800,000 Btu) 21.5 kW Flow: 17.3 scfm -50 kg H₂/day Recycled waste gas from (14.4 scfm) Hydrogen gas PSA used to heat reformer **ADG Plant PSA Usable Heat** Water-Gas Steam Gas Clean-up Compressor Reformer Shift **Electricity System** Reformate Reactor Fuel cell application Reformate RNG Supply: CH₄: ~7% Conditioned CH₄: ~55% **Feed Water** CO₂: ~19% Gas CO₂: ~38% 3 gph Solid waste CO: ~0.5% CH₄: ~89% O_2 : ~0.5% consists of gas H_2 : ~73.5 CO₂: ~2% N_2 :~3.5% clean-up filters Air Total Flow: & absorbents O₂: ~0.8% Other: ~3% (mostly sulfur ~34.6 scfm $N_2:~5\%$ 30 ppm H₂S compounds). Reformer's (SOFC: Other:~3.2% No liquid **Usable Heat** Flow rate: ~ 2.9 scfm effluents will be 0.01ppm H₂S ~19.0 Mcf/day 5.000 Btu/hr created. Some PSA: Flow rate: (17.5 to H_2) vented CO₂ ~ 31.7scfm) 8.0 scfm 1.5 to SOFC) 13.2 scfm

Example Gas Cleanup System for WWDG

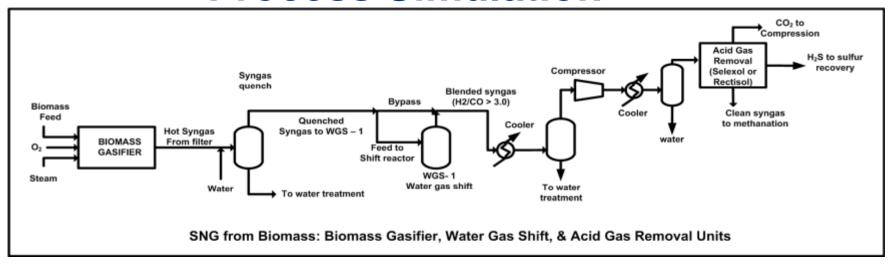
- > Configured a gas cleanup system utilizing a membrane module for CO₂ separation after H₂S removal
 - Passive system no moving parts, for increased reliability
 - Ease of operation virtually no maintenance requirements
 - Ease of Installation modular and lightweight and can be operated at wide turndown ratio



GTI's current project initiatives

- >Develop_{baseline} for ex pected levels of various constituents in landfills
- >Analyze clean-up techniques (membrane, reactants, and PSA).
- >Future work:
 - Develop understanding of impact each constituent has on pipeline operations and end use applications
 - Provide data to gas utilities
- >Utilities and Pipelines to take data and establish specification for their systems

GTI Biomass to Renewable Bio-gas Process Simulation



Commercial Systems Basis

- Oxygen-blown, pressurized fluidized bed gasifier (10 bar_a)
- Hydrocarbon reforming (including inherent CH₄)
- Sour water-gas shift to achieve H₂:CO >3
- Compression for commercial acid das removal for CO₂ and S
- USDOE simulation for AGR used in process
- Two stage + trim methanation reactor
- Dehydration to achieve gas pipeline specifications

~ 70% conversion efficiency



Removal of Trace Constituents The Technology is here –need cost reduction

- >Volatile Organics
 - Zeolites
 - Silica gel / adsorbents
- >Sulfur compounds
 - Activated carbon
 - Zinc oxide
 - Other biofiltering, hydro desulfurization
- >Siloxanes
 - Adsorption on activated carbon bed
 - Absorption in solvents
 - Adsorption on polymorphous graphite



R&D Recommendations

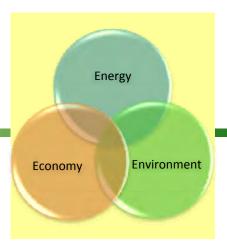
- Develop resource baseline data to better understand digester gas and landfill gas production (volumetric and constituent variability and availability)
- Initiate data analysis for operation of end use equipment (including fuel cell) with various levels of contaminants found in biogas to establish operating parameters.
- > Develop recycling technologies for gas clean-up techniques that can reduce O&M costs.
- > Perform economic analysis on optimal end-use application for renewable natural gas; vehicle fuel, pipeline injection, electricity generation, etc.
- > Build pilot gasification plant utilizing bio-feedstock

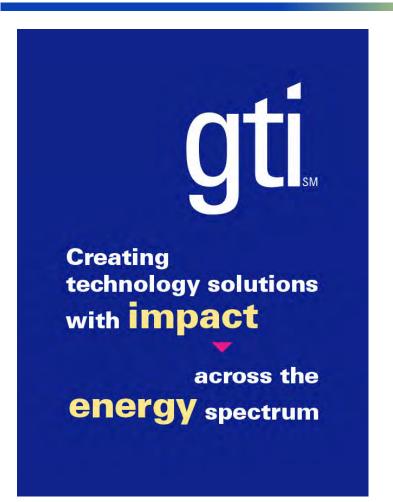


Summary

> Renewable Natural Gas

- Other than wind and solar, may be the lowest carbon renewable fuel available today
- RNG is being successfully injected into pipeline supply at over two dozen sites in the U.S.
- Additional analysis can help to reduce clean-up costs by better understanding constituent components and their potential impact on pipeline operations and consumers.
- Need to reduce costs of clean-up methods.
- Can play a major national role in reducing carbon emissions and meeting renewable goals if incentives comparable to those for other renewable energy sources are enacted





Thank you for being_{interested} in clean, reliable energy!

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